MOL.19970409.0087

CONCEPTUAL AND NUMERICAL MODEL OF INFILTRATION FOR THE YUCCA MOUNTAIN AREA, NEVADA

U.S. GEOLOGICAL SURVEY

Water Resources Investigation Report ##-###

DRAFT

Prepared in cooperation with the
NEVADA OPERATIONS OFFICE
U.S. DEPARTMENT OF ENERGY, under
Interagency Agreement DE-AI08-92NV10874

Dept.
Seal

version

INFIL_R1.WPD

September 20, 1996

CONCEPTUAL AND NUMERICAL MODEL OF INFILTRATION FOR THE YUCCA MOUNTAIN AREA, NEVADA

by Alan L. Flint, Joseph A. Hevesi and Lorraine E. Flint

U.S. GEOLOGICAL SURVEY

Water Resources Investigation Report ##-###

Prepared in cooperation with the
NEVADA OPERATIONS OFFICE
U.S. DEPARTMENT OF ENERGY, under
Interagency Agreement DE-AI08-92NV10874

Denver, Colorado
1996

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, Director

The use of trade, product, industry, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government

---

For additional information write to:

Chief, Earth Sciences Investigations Program
Yucca Mountain Project Branch
U.S. Geological Survey
Box 25046, MS 421
Denver Federal Center
Denver, CO 80225

Copies of this report can be purchased from:

U.S. Geological Survey
Earth Science Information Center
Open-File Reports Section
Box 25286, MS 517
Denver Federal Center
Denver, CO 80225

CONTENTS

ABSTRACT 1

INTRODUCTION 2
Background 2
Purpose and Objectives 4
Previous Work 5

PROCESSES, THE PHYSICS OF INFILTRATION 8
Field Water Balance 9
Precipitation 11
Run-on / Runoff 15
Infiltration 16
Evapotranspiration 19
Redistribution 23
Flow at the soil-bedrock interface 24
Net infiltration 25

STUDY AREA DESCRIPTION 26
Geographic and Physiographic Setting 26
Climate 28
Past 28
Present 31
Future 31
Geology 33
Distribution 35
Properties 35
Watershed Characteristics 36
Defined watersheds 37
Topographic surfaces 38
Soils 39
Distribution 40
Properties 41
Vegetation 43

DATA COLLECTION / DATA ANALYSIS 46
Precipitation 46
Run-on / Runoff 54
Infiltration 57
Evapotranspiration 59
Redistribution 60
Neutron hole moisture profile analysis 60

Geochemistry analysis 63
Flow at the soil-bedrock interface 66
Net infiltration 68

NUMERICAL MODEL 69
Precipitation 70
Run-on/Runoff 72
Infiltration 74
Evapotranspiration 74
Solar radiation 74
Modified Priestley-Taylor equation 75
Redistribution 77
Net infiltration 82
Model Calibration 83
Stochastic Simulations of Infiltration 85

ASSUMPTIONS AND LIMITATIONS 88

FUTURE WORK 89

SUMMARY 90

Appendix I -- All Yucca Mountain Project data referred to in this report, listed by data tracking number 104

Appendix II -- Neutron borehole locations and information used in numerical model 107

Appendix III -- Program MARKOV 108

Appendix IV -- Program PPTSIM 119

Appendix V -- Program INFIL 127

FIGURES

1. Location of a) North American Deserts and the original 3 sites for characterization, and b) physiographic provinces. 2
2. Yucca Mountain regional study area with Death Valley Ground-Water Unit and infiltration study boundary. 5
3. Field scale schematic of infiltration. 9
4. Diagrammatic water balance components using notation described in equation 1. 10
5. Conceptual model of the energy balance equation for evapotranspiration. 21
6. a)Water content and water potential at the soil-bedrock interface at a depth of 2.1 m in borehole USW UZ-N52. The horizontal lines are the air-entry water potentials for a 2.5 um open fracture and a filled fracture, and b) associated flux calculated as the hydraulic conductivity of the fracture times a unit gradient 25
7. Infiltration study area and modeling domain with original site-scale model boundary (Wittwer and others, 1992) and potential repository location. 27
8. Historical climate change estimates from a) SPECMAP studies with a hypothetical transfer to precipitation, b) high-frequency fluctuations in climate change from the GRIP studies and c) recharge estimated from climate change cycles using the Maxey-Eakin method 30
9. Predominate direction of weather patterns and seasonal sources of moisture across the southwestern U.S. 31
10. Map of area with general geologic designations (after Sawyer and others, 1994.) 35
11. Saturated hydraulic conductivity of the surficial bedrock units 36
12. Map of major watersheds at Yucca Mountain. 37
13. Map of soil thickness designated in 4 categories, 0 - < 0.5, 0.5 - < 3 m, 3 - < 6 m, and ≥ 6 m. 40
14. Map of surficial soils. 41
15. Relationship of a) soil texture to saturated hydraulic conductivity using Campbell (1985) for soil without rock fragments and modified to correct for percent rock fragments, and b) modeled versus measured conductivity 42

16. Moisture retention curves calculated from measured soil texture (Campbell, 1985) compared to measured data for soil model units a) 1, b) 2, and c) 4, and texture models for d) all soil model units 43
17. Map of vegetation associations. 44
18. Rate of rainfall for a) a summer thunderstorm and b) winter precipitation 47
19. Estimated daily precipitation for Yucca Mountain using 15 years of measured data simulated at 90 neutron boreholes. 49
20. Probability of occurrence of daily precipitation at Yucca Mountain using 3rd order Markov chains. A 4-day window was used and 1 equals precipitation. 50
21. Data and fitted model for the cumulative probability distribution of precipitation quantity at station 4JA a) for the month of February and b) for the month of July. 51
22. Probability distribution of precipitation quantity for a) precipitation data from Area 12 and b) precipitation data from Yucca Mountain. 53
23. Hydrograph for Pagany Wash and Wren Wash, March 11, 1995. 57
24. Map of maximum infiltration capacity into initially air-dry soil. 58
25. Map of minimum infiltration capacity. 58
26. Illustration of the change in infiltration capacity for soil model unit 5 with time, related to precipitation rate and minimum infiltration capacity 58
27. Map of field capacity of surficial soils 59
28. Field storage capacity of soils calculated as field capacity multiplied by soil depth 59
29. Measured evaporation pan data and calculated potential evapotranspiration using energy balance for 1991-1993. 59
30. Average depth of penetration of the wetting front for years 1990-1993 and soil depth for 34 boreholes (Flint and Flint, 1995). 61
31. Changes in water content over time and depth for borehole USW UZ-N1. 62
32. Changes in water content over time and depth for borehole USW UZ-N15. 63
33. Saturation, porosity and $^{36}Cl/Cl$ ratios for boreholes USW UZ-N15, USW UZ-N16, USW UZ-N17 and USW UZ-N11. ^{36}Cl data is indicated for depth ranges as between pairs of points. 66

34. Saturation, porosity and $^{36}Cl/Cl$ ratios for boreholes USW UZ-N53, USW UZ-N54 and USW UZ-N55. ^{36}Cl data is indicated over a depth range. 66
35. Water potential measurements near borehole USW UZ-N15 using heat dissipation probes, a) measured at 4 depths for 1995 and b) used to calculate flux. 68
36. One hundred-year stochastic simulations of precipitation at a) Yucca Mountain and b) Area 12. 71
37. Average annual precipitation distributed spatially using an elevation correlation. 72
38. Simulated daily evapotranspiration for Yucca Mountain using 15 years of measured precipitation simulated at 90 neutron boreholes 76
39. Volumetric water content simulated at one location in Split Wash for a) 15 years and b) 100 years using the YM stochastic rainfall model 81
40. Simulation of mean net infiltration for neutron boreholes using 100-year stochastic simulations of precipitation from a) Yucca Mountain and b) Area 12 83
41. Calibration of modeled net infiltration using neutron boreholes a) USW UZ-N50 and b) USW UZ-N63. 84
42. Precipitation modeled with no channel enhancement factor and with 30 percent channel enhancement factor compared to simulated average annual precipitation for 15 years of data. 84
43. Precipitation versus infiltration modeled for each borehole with no channel enhancement factor and with 30 percent channel enhancement factor, and mean yearly infiltration for all boreholes. Linear regressions predicting values for each data set are shown. 84
44. Precipitation versus net infiltration, modeled 100-year simulation, estimated using Maxey-Eakin method and calculated from neutron borehole data 85
45. Infiltration simulated using stochastic precipitation simulations with average annual precipitation values of a) 165 mm/year and b) 205 mm/year 86
46. Conceptual model of infiltration numerically modeled using average annual precipitation resulting in an average of 4.5 mm/year flux over the modeling domain 87
47. Close-up view of the potential repository area in figure 46 87
48. Alternative conceptual model of infiltration numerically modeled assuming all infiltration is

through the channels, and assuming an average of 10 mm/yr, resulting in an average flux of 0.5 mm/yr over the modeling domain 87

TABLES

1. Generalized lithostratigraphy of Yucca Mountain area and ages 34
2. Properties of rock matrix and fractures for all lithostratigraphic units exposed in the study area. 36
3. Surficial soil units recombined from mapped surficial units. 40
4. Summary of soil properties. 41
5. Plant species most commonly found at Yucca Mountain. 45
6. Model parameters and cumulative probability for various minimum amounts of daily precipitation for stations 4JA and Area 12 calculated for months 53
7. Infiltration fluxes estimated by the chloride mass balance method (adapted from Fabryka-Martin and others, 1994) with a comparison of point and areally averaged estimates of net infiltration. 64

CONVERSION FACTORS

Multiply	*By*	*To Obtain*
millimeter (mm)	0.03937	inch (in)
meter (m)	3.28	foot (ft)
watt (w)	0.2388	calorie per second (C/s)
kilopascal (KPa)	0.01	bar
kilometer (km)	0.6214	mile (mi)
square kilometer (km^2)	0.386	square mile (mi^2)
millimeter per year (mm/yr)	0.00328	foot per year (ft/yr)
cubic centimeter (cm^3)	3.531×10^{-5}	cubic foot (ft^3)
cubic centimeter per second (cm^3/s)	3.531×10^{-5}	cubic foot per second (ft^3/s)

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 9/5\ °C + 32.$$